BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Venus Lander Probe for Manned Planetary Missions - Case 233

DATE: July 3, 1967

FROM: P. L. Chandeysson

ABSTRACT

A Venus lander probe to be used on manned planetary encounter missions is described. This probe is designed to land and survive on the surface of Venus for about one hour. During this time a panoramic television picture and data on the surface bearing strength and atmospheric conditions are transmitted to the manned vehicle. Total probe weight before deployment from the manned vehicle is estimated at 580 pounds.

[redacted]

(NASA-CR-154352) VENUS LANDER PROBE FOR MANNED PLANETARY MISSIONS (Bellcomm, Inc.) 16 p

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MEMORANDUM FOR FILE

I. INTRODUCTION

The Venus lander probe is one of a group of instrumented, unmanned vehicles to be deployed from the manned spacecraft during planetary encounter missions. It consists of a landing capsule to make measurements on the surface and an entry spacecraft to transport the landing capsule through space and the high speed atmospheric entry. The landing capsule is ejected from the entry spacecraft after atmospheric entry, falls in a fin stabilized attitude to the surface, and lands on a crushable impact limiter which covers the lower half of the capsule. Protected by thermal insulation and cooled by melting ice, the capsule survives for about one hour on the surface and transmits its data directly to the manned vehicle. The general arrangement of the entry spacecraft containing the landing capsule is shown in Figure 1.

The purpose of the Venus lander probe is to determine the feasibility and usefulness of surface landing vehicles in the scientific exploration of Venus. If this mode of operation proves successful, the lander probe will act as a precursor to more elaborate landing probes such as a long life surface geophysics laboratory probe. The lander probe should demonstrate the capability of a vehicle to make a successful landing on Venus and to erect and deploy experiments in a useful manner. It should determine which of the various types of terrain discerned by remote sensors is more suitable for landing so that the subsequent landers can be targeted to favorable areas. It should also return basic data about the surface topography, bearing strength, and atmospheric conditions to aid in the design of subsequent landing vehicles.

Because of the great uncertainty in the Venus surface environment, the landing capsule is designed to operate successfully over a wide range of atmospheric and surface conditions. It can accommodate a greater range of surface atmospheric density and pressure than currently expected[1] and can survive landings off vertical by as much as 45°. The thermal control equipment can protect the payload under the maximum expected heating conditions. The vehicle is equipped with legs to stabilize it in an upright position so that, on a level surface, it resists the overturning force of a wind of about 20 m/sec at the maximum expected density. With no wind, it is stable on a slope of 50°. It is even designed to float on a liquid surface in an upright attitude. If the surface proves so inhospitable as to consistently prevent successful operation of this vehicle, other types of probes such as a near surface floater probe should probably be considered for exploring the surface in preference to advanced landers.

II. MISSION PROFILE

The lander probes, enclosed in individual sterilization canisters, are stored in the probe hangar of the manned vehicle until deployment. Deployment occurs about one to three days prior to encounter and consists of ejecting the probe and sterilization canister from the probe hangar, separating the probe from the canister, and establishing communications between the manned vehicle and the probe.

The probes are then commanded to the proper attitude for the injection propulsion maneuvers which will cause them to intercept the planet one to three hours before periapsis. This variation in early arrival time is needed to allow the one hour data transmission times of the probes to be staggered since the beam width of the manned vehicle receiving antenna is too narrow to receive data from all the probes simultaneously. A sterilizable liquid propellant rocket is used for the injection and subsequent midcourse maneuvers and is jettisoned after the final midcourse. Optical tracking and transponder ranging from the manned vehicle provide data for the midcourse maneuvers.

During cruise the probe is attitude stabilized using the sun as one reference direction to simplify the thermal control problems. Roll control is maintained using an Earth, Venus, or stellar reference. The vehicle is commanded to an inertially stabilized attitude for injection, midcourse, and atmospheric entry. Just before entry the landing capsule is activated and its operational status is transmitted to the manned vehicle. Data from all capsule instrumentation is transmitted continuously from this time until the batteries are exhausted.

The probe enters the atmosphere, becomes aerodynamically stabilized and decelerates. As terminal descent velocity is approached, the landing capsule is separated from the entry spacecraft by ejection through the nose of the entry shell which has been opened by shaped charges. Aerodynamic forces aid this ejection since the ballistic coefficient of the capsule is about three times as great as that of the entry spacecraft. As soon as the landing capsule clears the entry spacecraft its radio transmissions can be received by the manned vehicle.

The landing capsule accelerates to terminal velocity aerodynamically stabilized by four fins. It impacts the surface at a velocity of 150 fps in the minimum density model atmosphere of Reference 1. The spring loaded legs are unlatched by the impact and fold outward to stabilize the capsule, lifting the impact limiter off the surface as shown in Figure 3. This action also uncovers the window of the panoramic television camera and folds the fins down to reduce the overturning moment of surface winds.

The manned vehicle monitors the data transmission during capsule descent, landing, and surface operations. On the surface a panoramic television scan is taken using artificial illumination if necessary. A series of wind velocity and atmospheric pressure and temperature measurements are made. The landing deceleration and subsequent inclination are measured, and the depth of penetration of four soil penetrometers attached to the legs is observed by the television camera. The data are digitalized and transmitted to the manned vehicle at a rate of about 2500 bits per second over an omnidirectional antenna.

The operating lifetime is limited by the time the high gain antenna on the manned vehicle is available to receive data. The capsule communications subsystem is sized to transmit the total data return (about 10^7 bits) in one hour starting when the manned vehicle is still three hours from periapsis passage. This is in accordance with the requirements for a nominal Venus encounter[2], and provides time for the manned vehicle to monitor other probes with the high gain antenna. The useful life of the probe is therefore one hour and is ended when the approaching manned vehicle switches its receiving antenna to a different probe.

III. PAYLOAD SUBSYSTEM

The payload subsystem for the Venus lander probe consists of instruments to measure the surface topography, bearing strength, and atmospheric conditions. Table I gives the estimated weight, power, and data generated by these instruments during the one hour nominal lifetime. The instruments are designed to survive a 1500 g shock, as are all the landing capsule subsystems.

The facsimile television is used to observe the local terrain, surface illumination, and penetration of the soil penetrometers. It makes a panoramic scan in one hour and has a vertical field of view of about 50° as shown in Figure 4. Resolution is about 5 milliradians; i.e., line pairs 5 mm wide can be resolved at 1 meter distance. The generated data rate is compatible with the data transmission rate of the communications system, thereby making television data storage unnecessary. Facsimile television cameras are very rugged, having been built to operate during and after a 3000 g shock.

The camera is equipped with an illuminator which is turned on automatically if the natural illumination is too low. The illuminator projects a narrow beam of light which is synchronized mechanically with the camera scanning beam. By illuminating only the part of the scene being observed, the illuminator power requirements are significantly reduced. To achieve usable illumination at a range of 100 feet requires only about 5 watts of electrical power for the synchronous illuminator.

The anemometer consists of six pressure taps equally spaced around the cylindrical stem which projects up from the camera housing. Taps on opposite sides of the stem are connected across differential pressure transducers. Wind velocity in a plane perpendicular to the stem can be calculated from the three simultaneous differential pressure readings and the atmospheric density. The pressure distribution around a cylinder requires at least six pressure taps to determine the wind speed and direction. The readings are sampled, digitalized, and transmitted during short periodic breaks in the television transmission. The maximum gust indication is also recorded and transmitted a few times during the one hour experiment lifetime.

The surface static pressure is measured by a high pressure ($\sim$ 1000 psi) transducer connected between one of the anemometer pressure taps and a small vacuum bottle which serves as a reference pressure. The capsule internal pressure ($\sim$ 1.5 psia) is also measured relative to the pressure in the vacuum reference. These instruments are essentially aneroid barometers.

Thermocouples on the landing capsule exterior measure the ambient temperature. Additional thermocouples are used to monitor the temperature of certain internal parts. The reference junction is located in the melting ice of the thermal control subsystem.

The impact accelerometer measures the deceleration time history of the impact as the capsule lands on the surface. From this information and a knowledge of the impact velocity and physical properties of the vehicle, rough information about the surface dynamic bearing strength can be deduced. The accelerometer output is sampled several times during impact, digitalized, and stored for transmission to the manned vehicle.

The inclinometer measures the attitude of the capsule with respect to the gravitational vector. Since the output of this instrument is sampled several times during the one hour surface lifetime, it gives information about the stability of the vehicle. This information, when combined with the surface wind data, may give some indication about the stability of the surface. The instrument consists of an insulating shell partly filled with mercury. Electrical contacts on the inside of the shell sense the position of the mercury.

The soil penetrometers are four spring-loaded plungers attached to the stabilizing legs. A combination of different plunger areas and spring rates could be used to gain information about the surface static bearing strength. The plungers are released shortly after landing and the depth of penetration is indicated on graduated rods visible in the television picture. Release might be effected by a fusable element designed to melt after a short exposure to the surface thermal environment. The soil penetrometers are the only instrumentation exposed to the surface environment; all other instruments are within the cool, low pressure environment of the capsule.

IV. OPERATIONAL SUPPORT SUBSYSTEMS

About nine-tenths of the landing capsule weight and the entire entry spacecraft are comprised of the operational support subsystems needed to support the operation of the 16 pound instrument payload in the capsule. Table II shows the weights of the landing capsule subsystems and Table III shows weights for the entry spacecraft. All of the probe subsystems are heat sterilizable within the sterilization canister. The capsule subsystems are designed to survive 1500 g loads; on the entry spacecraft, only the capsule ejection mechanisms and entry shell need be built to withstand the high g loading of steep atmospheric entry.

The capsule electrical subsystems, including the instruments, operate continuously beginning at activation just before atmospheric entry. Operation is monitored at activation by sensors on the entry spacecraft; after separation, operation is monitored directly by the manned vehicle which can receive signals from the capsule during its descent as well as after landing.

The capsule data handling subsystem consists of an analog-to-digital converter, data storage, and a sequencer to control the order of data transmission. The communications subsystem is a transmitter radiating 7 watts over an omnidirectional antenna. Two silver-zinc primary batteries provide electrical power; either one could operate the capsule for two hours. The temperature control subsystem uses an evacuated superinsulation to isolate the internal parts of the capsule from the surface thermal environment and melting ice to stabilize the internal temperature. Heat leaks can be reduced so that the internally generated heat is the major load on the temperature control subsystem. The capsule structure subsystem consists of a high temperature resistant pressure vessel and secondary structure to support internal parts. The stabilizing legs are hinged to the pressure vessel and are equipped with fins to stabilize the vehicle during descent and floats to stabilize it on a fluid surface. The legs are deployed by spring driven actuators using dashpots to control the opening rate. The impact limiter consists of crushable steel honeycomb material with a maximum thickness of 8-1/2 inches. This is sufficient to reduce impact acceleration to 1500 g when landing at 150 fps.(3)

The payload subsystem of the entry spacecraft is the landing capsule itself as indicated in Table III. The capsule ejection mechanisms are the springs and pyrotechnics needed to effect separation. The sensors subsystem monitors the operational state of the entry spacecraft and the landing capsule. The command and data handling subsystem processes the commands from the manned vehicle and the data generated by the sensors subsystem. The communications subsystem is a tracking transponder with a low rate command and data transmission capability. The flight control subsystem consists of sensors, attitude control jets, and the autopilot which control the spaceflight attitude. Electrical power comes from primary batteries since the electrical loads are probably insufficient to justify solar arrays. A tracking beacon is provided to allow angular tracking with the optical telescope on the manned vehicle. The entry shell and heat shield weight has been estimated for a vehicle capable of entering the Venus atmosphere at angles up to 30°.(4) These subsystems bring the estimated entry spacecraft weight up to 400 pounds. The propulsion subsystem was sized to provide 500 meters/sec of velocity change using a sterilizable propellant combination with a delivered specific impulse of 325 seconds and a mass fraction of 0.8. This provides the 435 m/sec injection velocity change required to achieve one hour of early arrival for each day of launch before periapsis plus 65 m/sec for midcourse corrections. The sterilization canister weight was estimated on the basis of 1.6 pounds/ft^2.

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Attachments
  Tables I-III
  Figures 1-4

REFERENCES

(1) Evans, D. E., D. E. Pitts and G. L. Kraus, Venus and Mars Nominal Natural Environment for Advanced Manned Planetary Mission Programs, NASA SP-3016, 1967.

(2) Personal communication with C. L. Davis, Bellcomm.

(3) Personal communication with M. H. Skeer, Bellcomm.

(4) Personal communication with D. E. Cassidy, Bellcomm.

TABLE I - PAYLOAD SUBSYSTEM

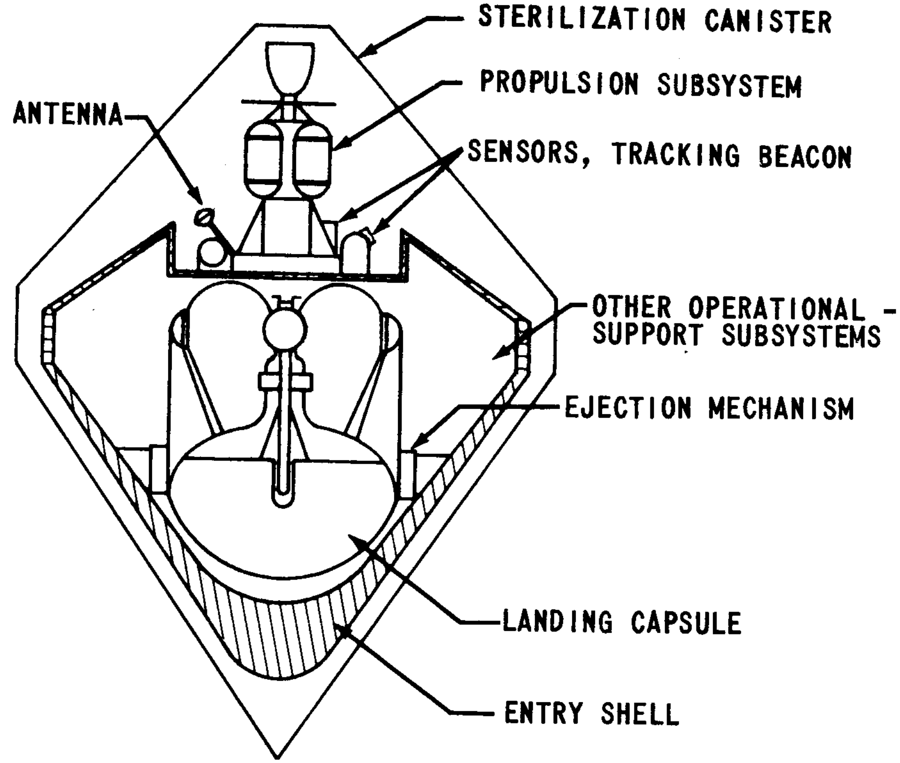
Instrument	Weight (Lbs.)	Power (Watts)	Total Data (Bits)
Facsimile Television Camera	7	5	9×10^6
Synchronous Illuminator	3	5	--
Anemometer	1-1/2	1-1/2	4000
Static Pressure Transducers	1/2	1/2	1000
Thermocouples	1	--	1000
Impact Accelerometer	1/2	1/2	200
Inclinometer	1/2	1/2	1000
Soil Penetrometers	2	--	--

TABLE II - LANDING CAPSULE SUBSYSTEMS

Subsystem	Weight (Lbs.)
Payload	16
Data Handling	3
Communications	7
Power	6
Temperature Control	15
Structure	28
Stabilizing Legs and Actuators	20
Impact Limiter	55
Total	150

TABLE III - LANDER PROBE SUBSYSTEMS

Subsystem		Weight (Lbs.)
Payload (Landing Capsule)		150
Capsule Ejection Mechanisms		10
Sensors		5
Command and Data Handling		5
Communications		10
Flight Control		25
Power		30
Tracking Beacon		5
Entry Shell (Heat Shield and Structure)		160
	Entry Weight	400
Propulsion		92
Sterilization Canister		88
	Gross Weight	580



LANDING CAPSULE	150
ENTRY SHELL	160
STERILIZATION CANISTER	88
PROPULSION SUBSYSTEM	92
OTHER SUBSYSTEMS	90
GROSS WEIGHT	580 LBS

FIGURE 1 - VENUS LANDER PROBE GENERAL ARRANGEMENT

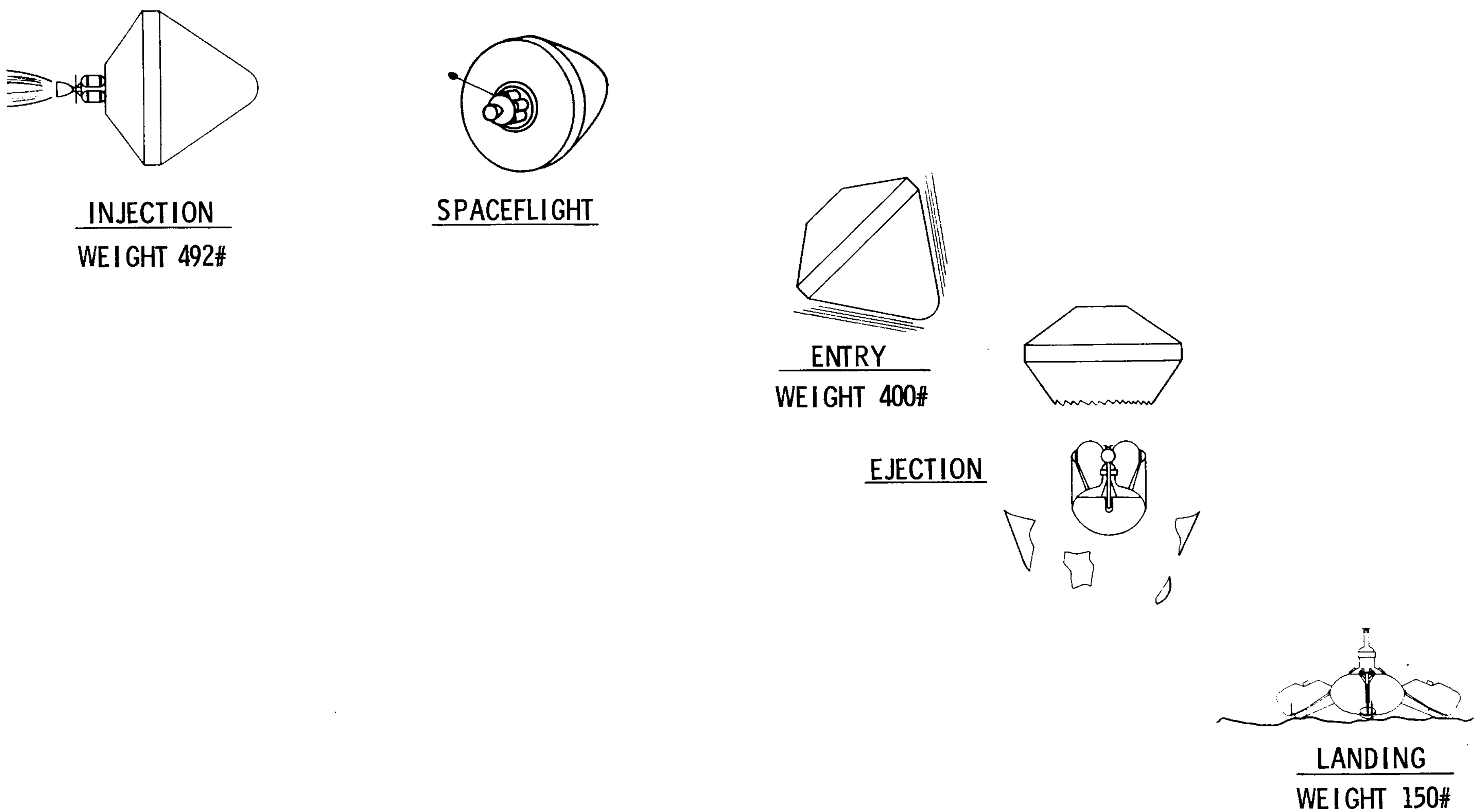


FIGURE 2 - VENUS LANDER PROBE MISSION PROFILE

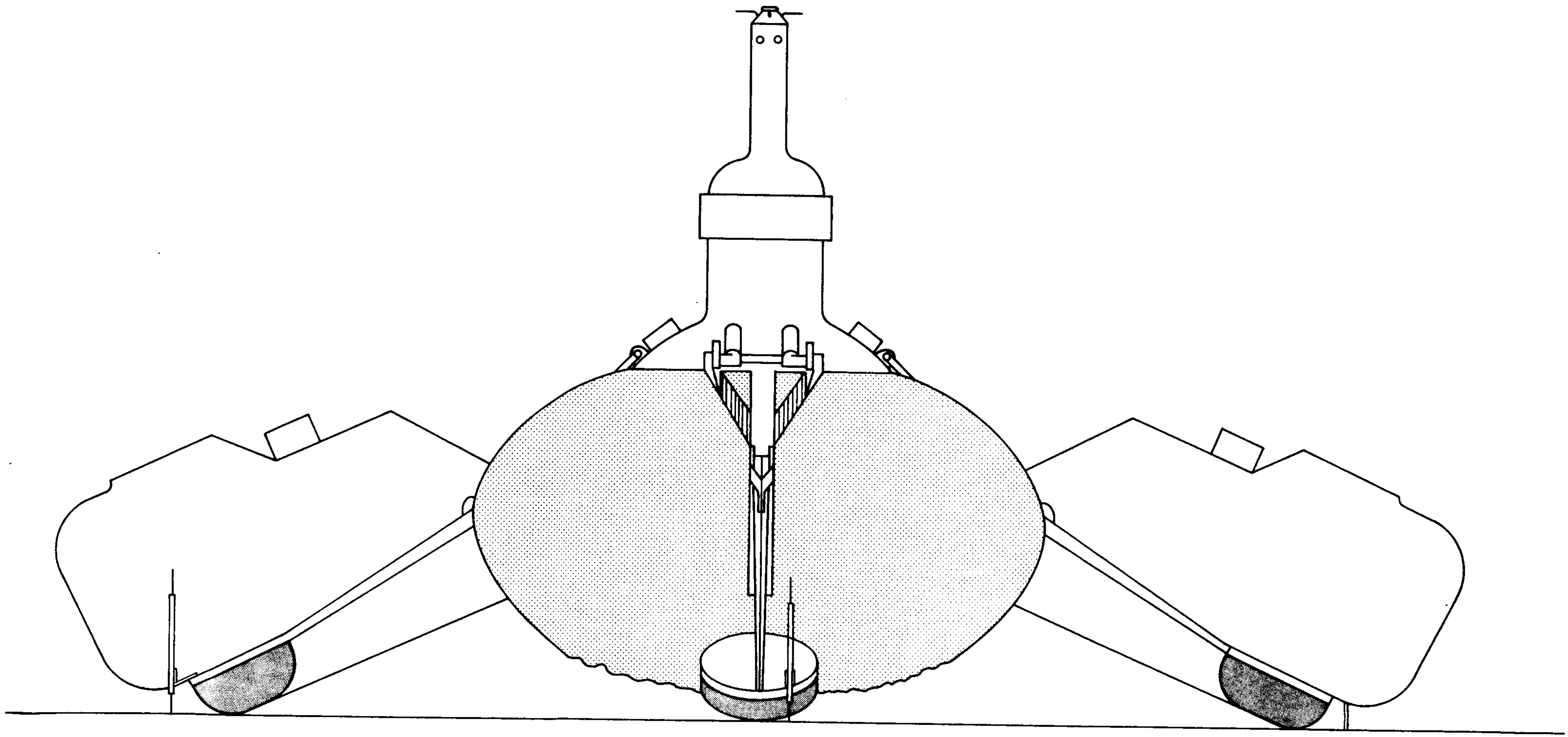


FIGURE 3 - LANDING CAPSULE IN LANDED CONFIGURATION

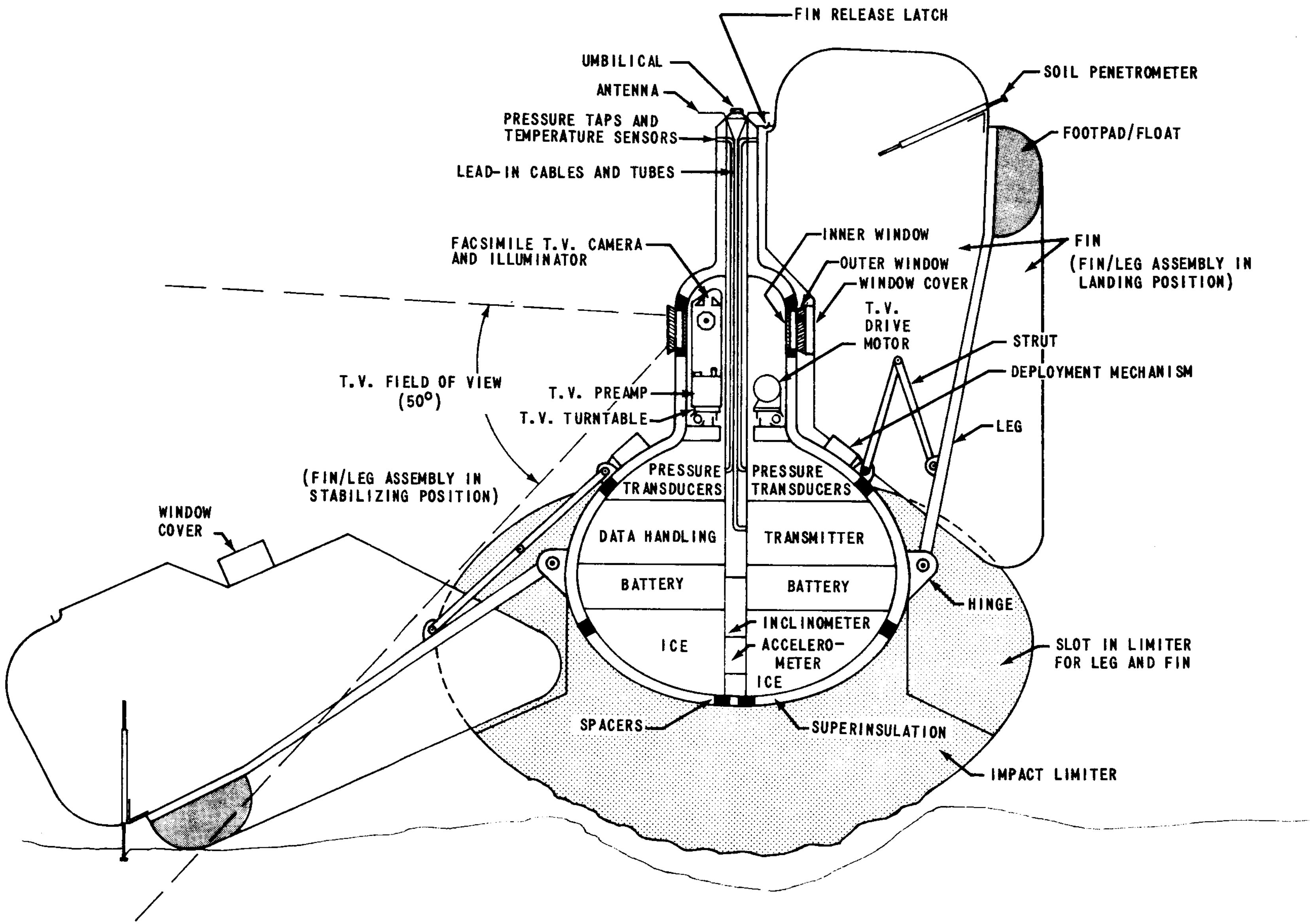


FIGURE 4 - LANDING CAPSULE INTERNAL ARRANGEMENT

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